Module 2: Basic Stormwater Principles

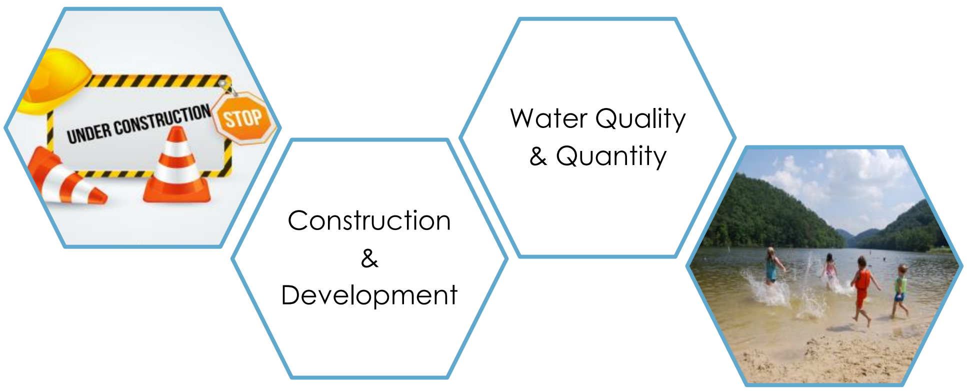
Objectives

- Generalize the goal of the Part II B water quality and quantity technical criteria.
- Explain how runoff characteristics can change as landcover conditions change.

2a. Overview

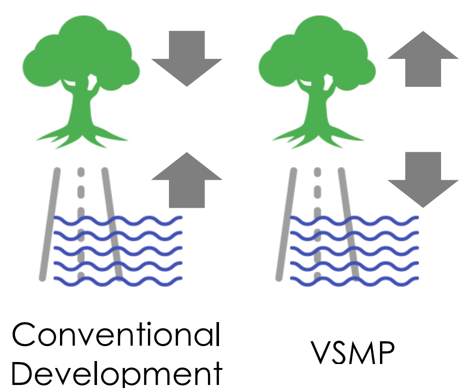
INSPECTORS AND STORMWATER MANAGEMENT

As an inspector for a VSMP you play a critical environmental role in your community by helping to confirm that construction and development activities follow the requirements of the Virginia Stormwater Management Program (VSMP).



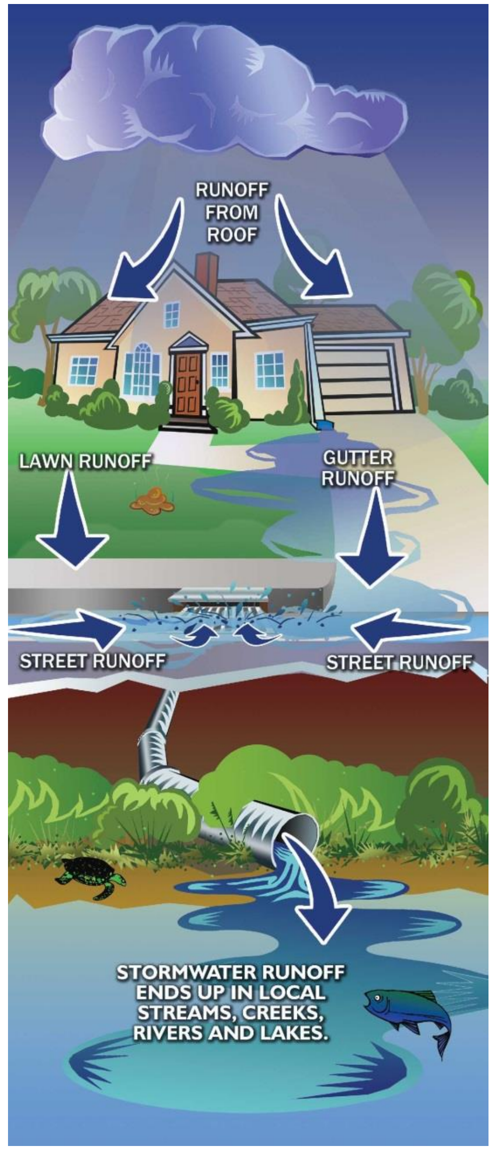
Conventional development has the potential to affect water quality and quantity through changes to a site's landcover. This change of landcover often results in the loss of natural processes and increased stormwater runoff which can have an impact on downstream properties and natural resources. Virginia has adopted a stormwater management approach that encompasses both environmental site design and the use of stormwater best management practices (BMPs) to maintain natural processes and reduce the amount of runoff that will leave a site. These topics are discussed in the following sections.

Understanding the connection between construction and development activities and water quality and quantity will add value to your role as an inspector as you communicate with individuals in your community about the requirements of the VSMP.



DEFINITION OF STORMWATER RUNOFF

Stormwater runoff occurs when the amount of precipitation exceeds the capacity of the ground to absorb water. Runoff washes off impervious surfaces like compacted soils, roofs, driveways, sidewalks, and roads, and carries sediment, trash, oil, fertilizers, and other pollutants to local waterways.



Courtesy NCDENR

VSMP TECHNICAL CRITERIA

The Virginia Stormwater Management Program includes technical criteria (II B and II C) that must be met in the stormwater management plan to address:

- ***<u>Water quality</u>*** for the protection of state waters from the pollutants that are carried off a developed site in stormwater runoff; and
- ***<u>Water quantity</u>*** for the protection of state waters from channel erosion and flooding that can result from an increase in the volume and flow of stormwater runoff that leaves a developed site.

The II B ***<u>water quality</u>*** technical criteria establish a threshold for total phosphorus that can be allowed to leave a site through stormwater runoff. Phosphorus is both a pollutant associated with land development and a marker that can be targeted for the minimization of other related pollutants. While phosphorus is naturally found in fresh water, even small increases can have adverse effects on water quality and aquatic life.

NOTE:

The energy balance equation may be used to comply with the Part II B water quantity criteria for channel protection, which also satisfies minimum standard 19 of the Erosion and Sediment Control Regulations.

Environmental Site Design

Environmental Site Design is the practice of using small-scale stormwater management practices, nonstructural techniques, and better site planning to mimic natural runoff characteristics and minimize the impact of land development on water quality and quantity by reducing the amount of stormwater runoff that will leave a site. Low impact development (LID) is a design approach that's included in ESD.

ESD promotes:

- Conserving natural features and resources (e.g., drainage patterns, native soil, native vegetation);
- Minimizing impervious surfaces (e.g., pavement, concrete channels, rooftops);
- Slowing down runoff to maintain discharge timing and to increase infiltration and evapotranspiration on the development site; and
- Using other non-structural practices or innovative technologies approved by DEQ.

Best management practices (BMPs)

If a site's design does not initially meet the technical criteria, then DEQ approved best management practices (BMPs) must be added to the design to reduce stormwater runoff and/or remove pollutants from stormwater runoff. The 15 non-proprietary BMPs are discussed later modules 6 and 7.

SUMMARY

Different landcover conditions result in different stormwater runoff characteristics. For example, a forested area will have very little stormwater runoff flow compared to an impervious parking lot.

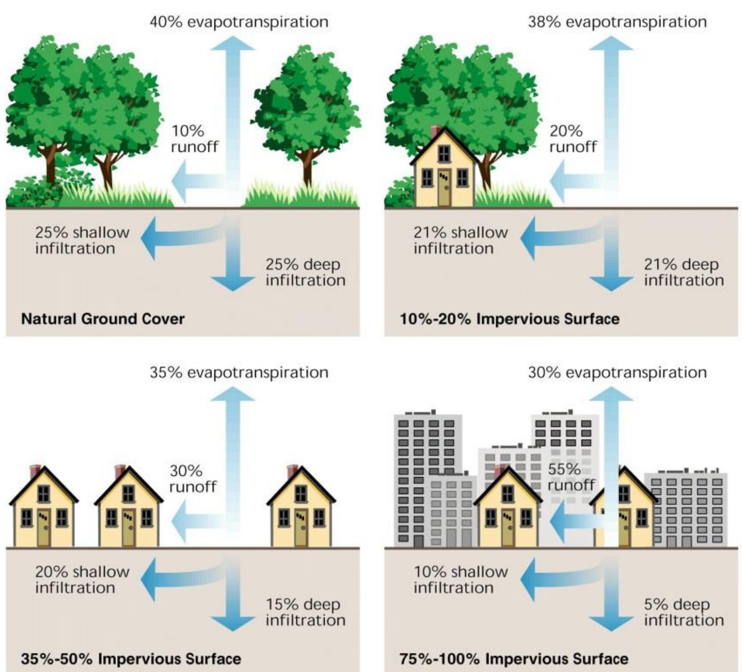
Therefore, minimizing land cover changes and using Environmental Site Design principles will:

1. Enhance the natural functions of beneficial site resources, and
2. Reduce the amount of runoff that will leave a site, which assists in meeting the Part II B water quality and water quantity criteria.

2b. Effects of Landuse on the Hydrologic Cycle

As population growth increases, the demand for buildings, homes and infrastructure also increases. In the past, development often led to the loss of many important environmental processes including:

- Reduced evapotranspiration, interception, and infiltration from the loss of vegetation;
- Reduced infiltration from the removal of topsoil and compaction of subsoil;
- Reduced groundwater recharge and stream base flows from increased stormwater runoff over impervious surfaces;
- Reduced infiltration from the use of built drainage systems such as gutters, storm sewers and smooth-lined channels; and
- Declining watershed health from increased imperviousness.



Relationship between impervious cover and runoff
Federal Interagency SWRG, 1998

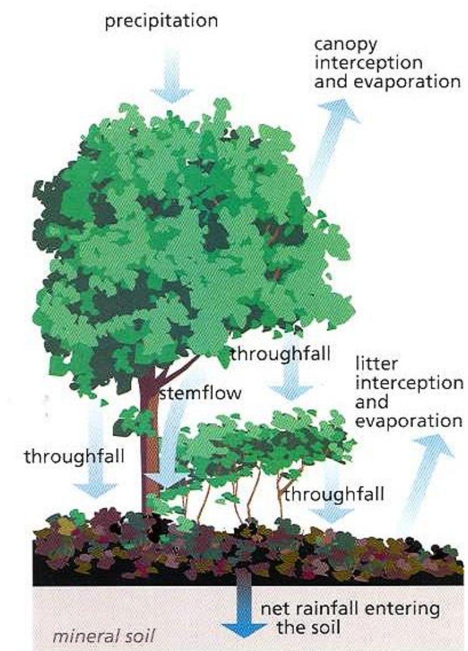
It’s important to remember that altering one component of the water cycle affects all other elements of the cycle. Roads, buildings, parking lots and other impervious surfaces prevent rainfall from infiltrating into the soil and significantly increase runoff volume and flow.

As natural vegetation is replaced with impervious cover and natural drainage patterns are altered, the amount of evapotranspiration and infiltration decreases and stormwater runoff substantially increases.

Reduced evapotranspiration and infiltration from loss of vegetation

In a natural Virginia woodland or meadow, very little rainfall leaves the site as runoff. Runoff will occur from most wooded sites only after more than an inch of rain has fallen. In an undeveloped area, more than half of the annual amount of rainfall returns to the atmosphere through evapotranspiration.

Turf grass, which has commonly been used to replace natural vegetation, produces more runoff than natural open space and forestland, often because it is laid over compacted soil. Turf grass management can involve the application of large amounts of fertilizer and pesticides, which can be picked up by stormwater runoff and carried to local waterways.



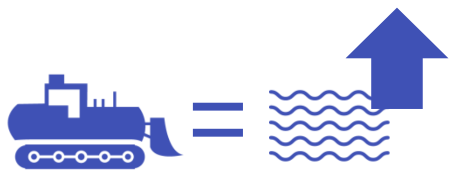
The benefits of tree canopy for stormwater management

NOTE:

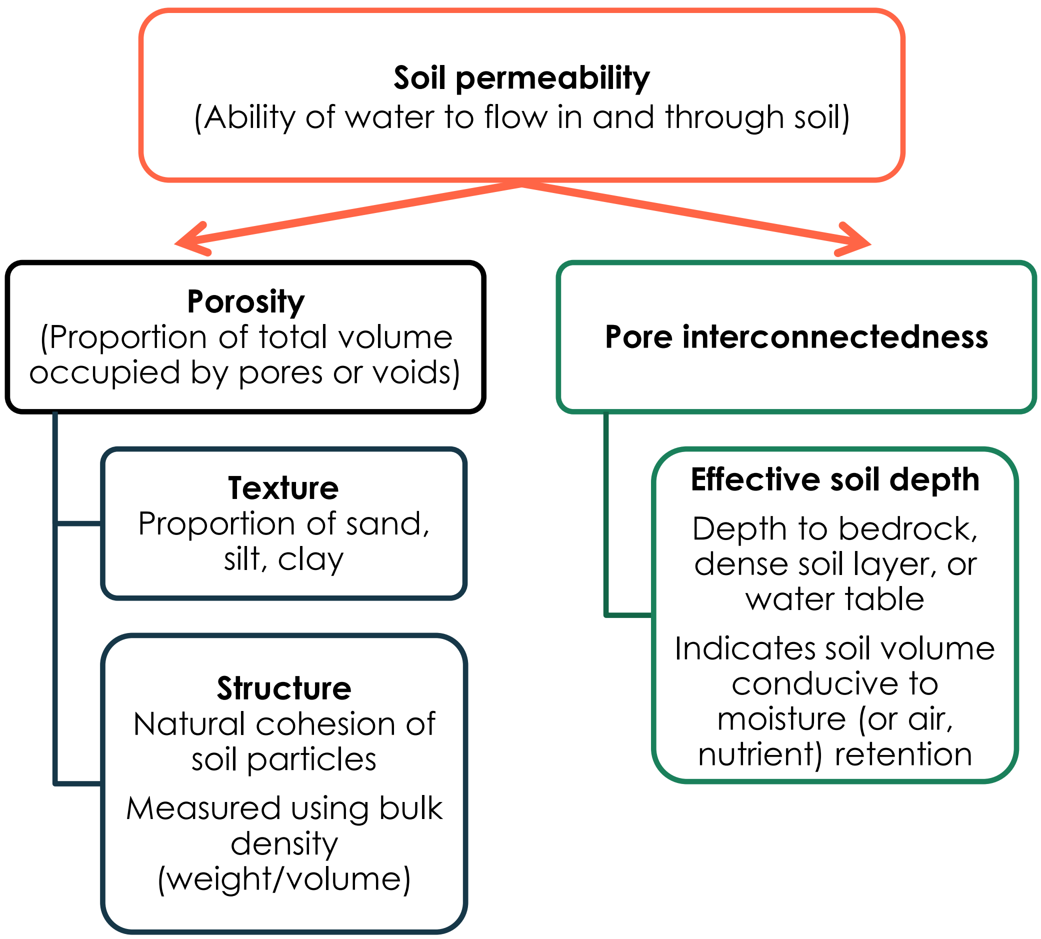
Removing vegetation or changing the land type from woods and meadow to residential lawns reduces evapotranspiration and infiltration and increases stormwater runoff volume and flow.

Reduced infiltration from removal of topsoil and compaction of subsoil

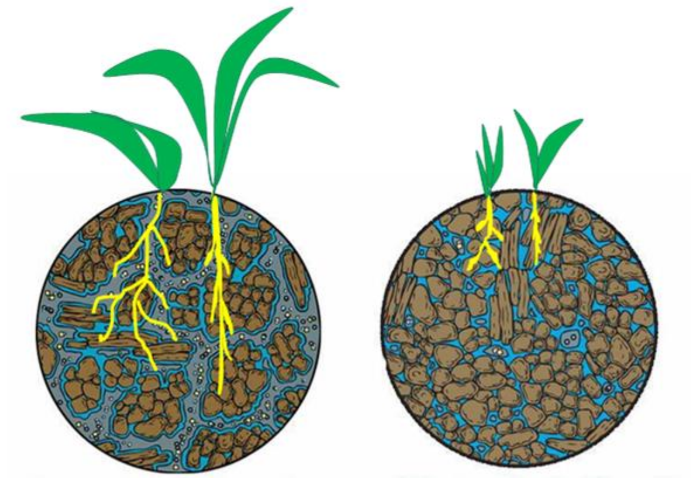
When soil is disturbed by grading, stockpiling, and heavy equipment traffic, the soil becomes compacted, structure is lost, and the ability of water to flow in (infiltration) and through (percolation) the soil decreases. ***When this happens, the soil's ability to take in water (<u>permeability</u>) is substantially reduced and surface runoff increases***. Soil permeability is very important when selecting BMPs that rely on infiltration to remove pollutants or reduce runoff volumes.



Soil basics:

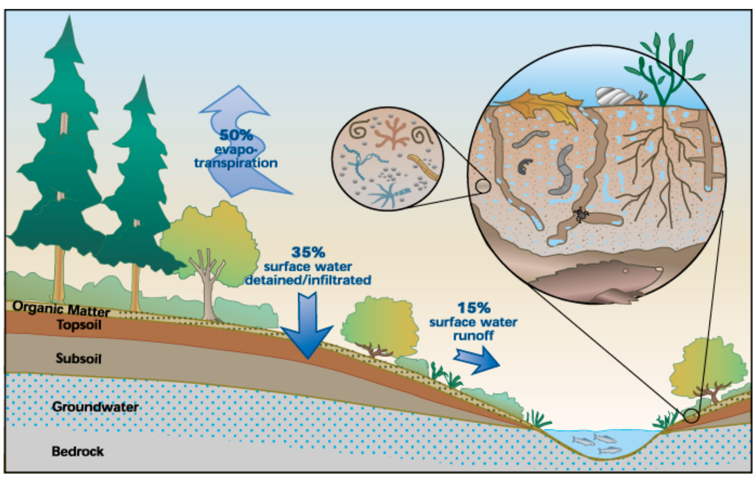


Bulk density:



Lower bulk density Lower Weight More pore space	Higher bulk density Higher Weight Less pore space

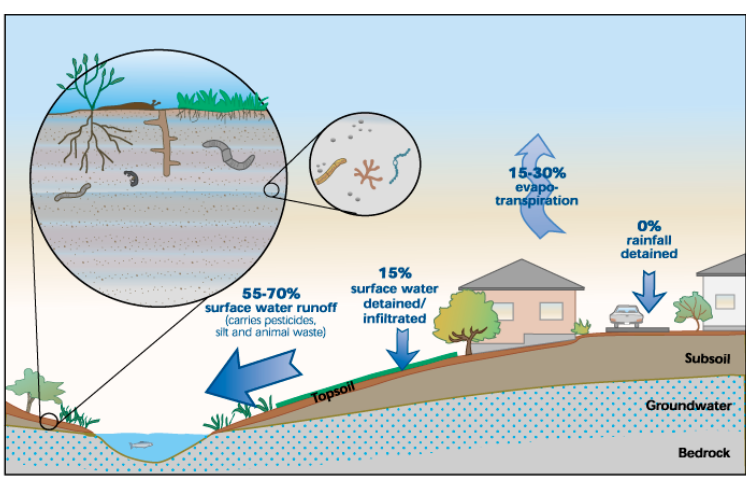
Adapted from International Society of Arboriculture, Bugwood.org



Before land disturbing activity

- Thick topsoil, organic matter
- Soil structure and texture intact
- Good soil porosity (enhanced by biological channels – plants roots, soil organisms)

Permeable soils = very little surface runoff



After land disturbing activity

- Soil structure lost (compacted)
- Thin topsoil (if any)
- Organic matter often lost
- Soil porosity and permeability decrease

Compacted soils = more surface runoff

You should know:

Construction equipment can cause such profound soil compaction (topsoil and subsoil) that the soil's bulk density can approach that of concrete and as a result, come functionally impervious.

Construction soil compaction
Photo credit: Virginia Tech archived photos http://clic.cses.vt.edu

Compacted soil
Photo credit: Center for Watershed Protection

Table 2-1
Common Bulk Density Measurements

Land Surface/Use	**Bulk Density**
Undisturbed Lands Forest & Woodlands	1.03 g/cc
Residential Neighborhoods	1.69 to 1.97 g/cc
Golf Courses - Parks Athletic Fields	1.69 to 1.97 g/cc
Concrete	2.2 g/cc

Consider also:

Soils with the highest permeability (Table 2-2) are often considered most suitable for construction ***(and it is this characteristic that is typically reduced or eliminated by the construction process)***.

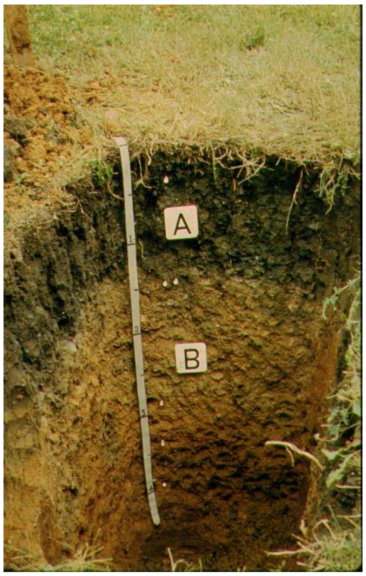


Table 2-2
USDA-NRCS Estimates of Annual Groundwater Recharge Rates, Based on Soil Type

Hydrologic Soil Group (HSG)	Recharge Rate
Hydrologic Soil Group A	18 inches/year
Hydrologic Soil Group B	12 inches/year
Hydrologic Soil Group C	6 inches/year
Hydrologic Soil Group D	3 inches/year

NOTE: Average annual rainfall varies from approximately 42 - 48 inches across Virginia

All of these factors have some effect on how water will move through the soil. It is important to understand these factors when designing an appropriate stormwater system at a particular location. These factors are especially critical when considering BMPs that rely on infiltration to reduce runoff volume and/or remove pollutants.

Reduced groundwater recharge and reduced stream base flows

When precipitation runs off impervious surfaces rather than infiltrating and recharging the groundwater, it alters the hydrologic balance of the watershed. As a consequence, a stream's base flow is deprived of constant groundwater discharge, and the flow may diminish or even cease. Wetlands and headwaters reflect changes in groundwater levels most profoundly, and the reduced flow can stress or even eliminate the aquatic community.

During a drought, reduced stream base flow may also significantly affect the water quality in a stream. As the amount of water in the stream decreases, the oxygen content of the water often falls, affecting the fish and macroinvertebrates that live there. Reduced oxygen content can also lead to the release of pollutants previously bound up in bottom sediment.

Reduced infiltration from built or traditional drainage systems

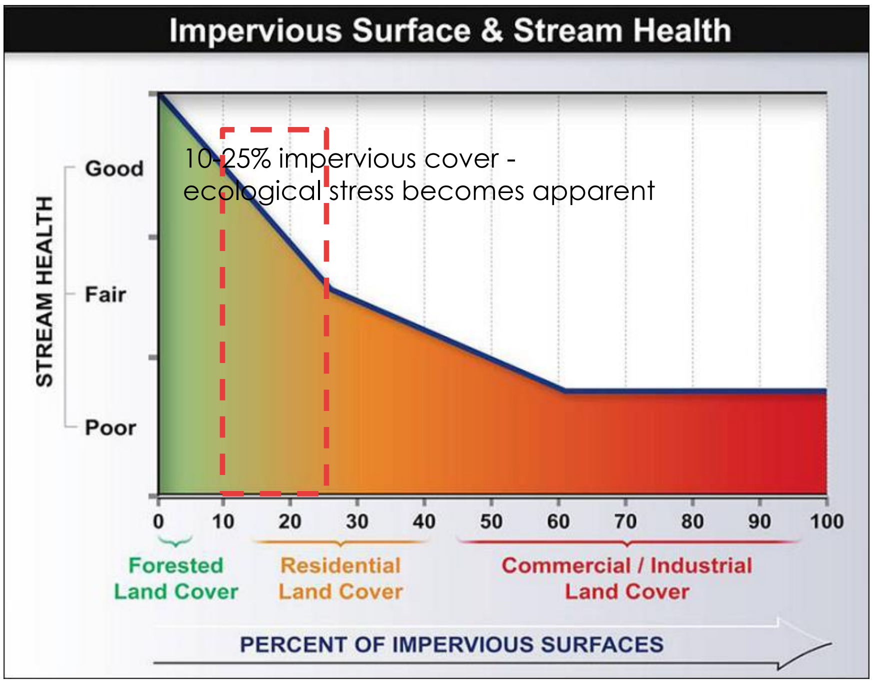
As stated earlier, depending on the magnitude of changes to the land surface, the total runoff volume can increase dramatically. This effect is further intensified by drainage systems such as gutters, storm sewers and smooth-lined channels that are designed to quickly carry runoff to rivers and streams.

Photo credit: ARC, 2001

Photo credit: Chesapeake Bay Stormwater Training Partnership

Declining watershed health from increased imperviousness

The amount of impervious cover in a watershed has been linked to the overall health or, conversely, degradation of that watershed. Research has shown that when impervious cover in a watershed reaches between 10 and 25 percent, ecological stress becomes apparent (Schueler et al., 2009). Beyond 25 percent impervious cover, stream stability is reduced, habitat is lost, water quality is degraded, and biological diversity is diminished. This relationship is displayed in the graph below.



The Impervious Cover Model:
How Imperviousness Impacts
Stream Health
Chesapeake Bay Stormwater Training Partnership

Table 2-3

Typical Site Impervious Coverage of Land Uses in the Northeast U.S.

Land Use	% Impervious Cover
Commercial and Business District	65-100
Industrial	70-80
High Density Residential	45-60
Medium Density Residential	35-45
Low Density Residential	20-40
Open (Natural Areas)	0-10

Source: MADEP, 1997; Kauffman and Brant, 2000; Arnold and Gibbons, 1996; Natural Resource Conservation Service, 1975

Note: Table values reflect impervious within specific land uses, not overall watershed imperviousness.

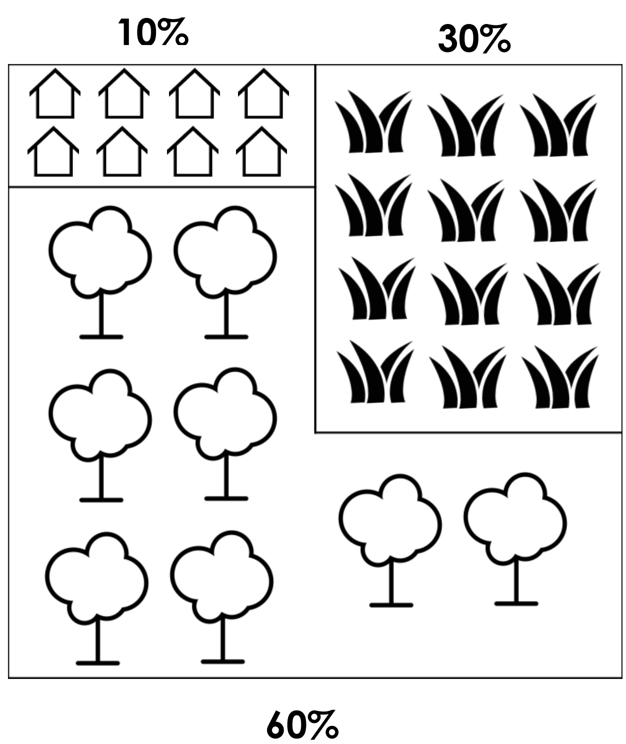
- Typical single-family home residential neighborhoods ranges from 15 to 60 percent impervious cover.
- In watersheds with significant residential, commercial, and industrial development, ***overall watershed imperviousness often exceeds ecological stress thresholds.***

As noted earlier, compacted soils at many land development sites result in vegetated surfaces that are, in many instances, nearly impervious and produce far more runoff than the natural (pre-development) soil did.

LANDUSE AND THE PART II B WATER QUALITY CRITERIA

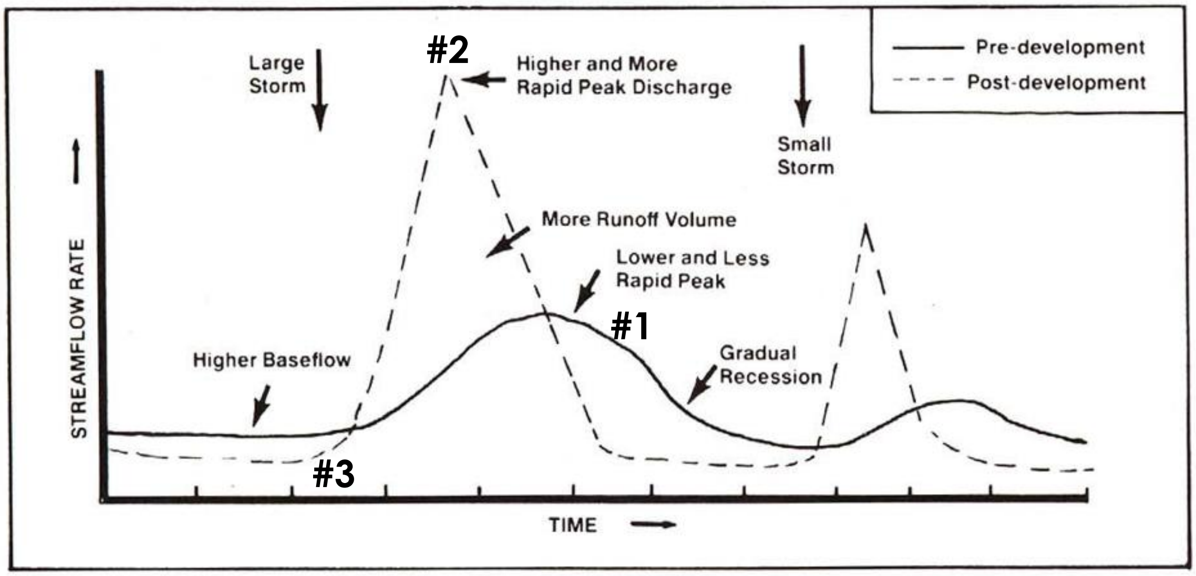
As mentioned in the overview, the Part II B water quality criteria establish a baseline of 0.41 lbs/acre/year of total phosphorus that can be allowed to leave a site through stormwater runoff. The Virginia Runoff Reduction Method uses the Simple Method (modified to include impervious, managed turf and forest/open space) to calculate how much stormwater runoff and phosphorus is expected to leave a site ***based on landcover conditions***.

0.41 lbs./acre/year of total phosphorus is based on 10% impervious cover, 60% forest cover and 30% turf cover. 10% impervious cover was adopted from the Impervious Cover Model shown above as that's when ecologic stress becomes apparent. Managed turf is included in the calculation since increased runoff and pollutant levels are expected with this land cover type.



2c. Impact of Stormwater Runoff on Stream Channels and Flooding

The Part II B water quantity criteria address channel and flood protection because as stormwater runoff increases, there is a direct impact on stream channels and flooding. The hydrograph below shows how differently a stream responds to a storm and stormwater runoff in a pre- and post- development watershed.



Pre- and Post-Development Stormwater Runoff Hydrographs

1. Following a storm in a ***pre-development*** watershed, the peak discharge, or flow that occurs when the maximum flood state, or depth, in a stream is reached, gradually increases and gradually declines (curve is rounded).

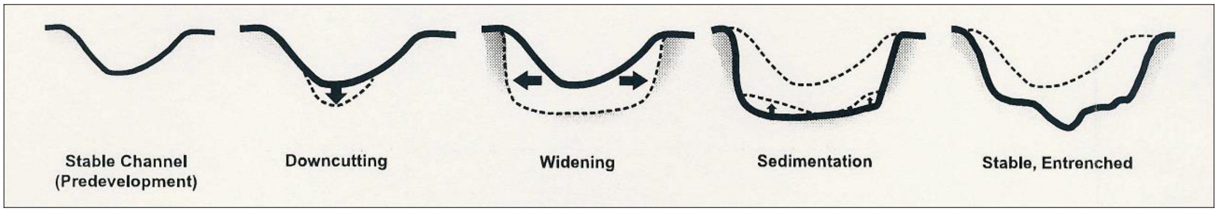
2. After a storm in a ***post-development*** watershed***,*** the peak discharge can be two to five times higher than in a ***pre-development*** watershed. This characterization translates into the sharp peak and increased size of the post-development hydrograph.

   This happens in a ***post-development*** watershed because there is more impervious surface and less opportunity for evapotranspiration and infiltration.

3. It takes less time for runoff to travel over the impervious surface in a ***post-development*** watershed, so it takes less time for runoff to reach a stream (time of concentration). The energy of stream flows ranging from low to bankfull flows can most quickly alter a stream channel's physical shape and size.

The combination of greater volumes of runoff occurring more often and at higher flow rates, even in small storm events, can create:

- Altered stream flows that can affect water conditions and habitat for fish;
- Channel erosion, widening and downcutting that can degrade stream habitat and produce substantial increases in sediment loads from accelerated erosion; and
- Increased frequency of flooding and floodplain expansion.

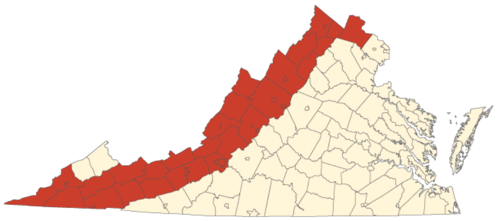


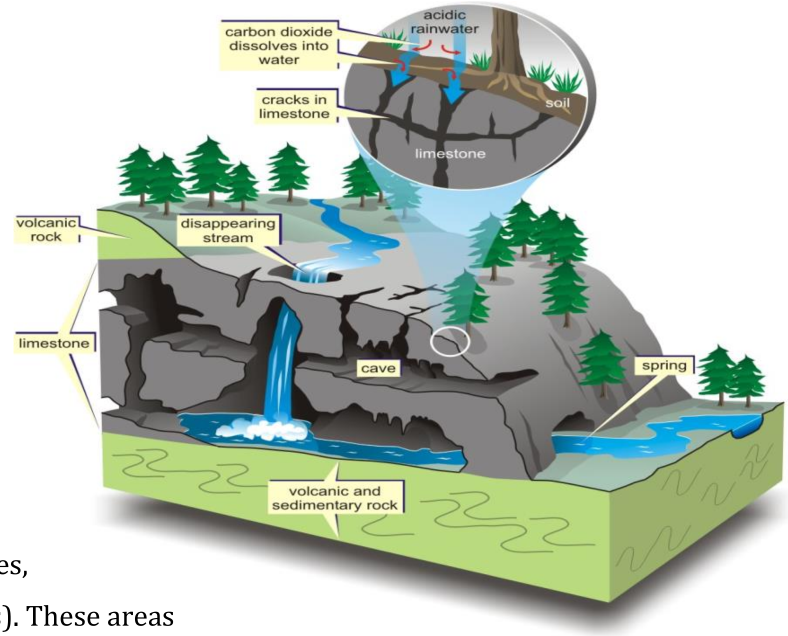
Typical changes to a stream's physical characteristics due to watershed development

LANDUSE AND THE PART II B WATER QUANTITY CRITERIA

The Part II B water quantity criteria attempts to assure that runoff from a developed site will not cause damage to downstream properties or natural resources including not exceeding the capacity of a receiving stream channel for protection against channel erosion and flooding. This is done by maintaining the after-development runoff rate of flow and characteristics that replicate, as nearly as practicable, the existing pre-development runoff characteristics of the site. Alternatively, the criteria require improvements where channel erosion and/or flooding have already occurred.

2d. Karst Areas





The valleys of western Virginia are underlain largely by soluble bedrock (limestone and dolomite), which slowly dissolved over the millennia to form karst areas with unique hydrologic systems (fissures, sinkholes, underground streams, and caverns). These areas supply drinking water and support base flow of local streams.

The effects of poor stormwater management are exacerbated in karst settings:

- Karst terrain soils are not very permeable
- Rainwater is diverted underground through fractured bedrock or other karst features to aquifers and springs without the usual natural attenuation (natural ground filtration) process that accompanies groundwater flow (leads to increased contamination of groundwater and base stream water)
- After development, increased surface runoff is typically routed overland to surface streams or discharged to karst features which lack sufficient capacity
- Increased stormwater ponding or infiltration form sinkholes (surface sediments collapse due to the intrusion of stormwater runoff)
- More runoff deprives the karst system of recharge (groundwater table and base stream flows diminished)

2e. Summary

Summary of potential problems with stormwater runoff

High Stormwater Volume and Velocity

- More impervious surfaces lead to less ground infiltration, more higher energy runoff
- Increased stream volumes and flow rates, flooding, more erosion

Pollutants in Stormwater Runoff

- Pollutants transported untreated to our waterways (nutrients, sediments, toxics, litter, debris, etc.)

Ecological Impacts

- Altered or lost habitats (aquatic, riparian)
- Reduced richness and diversity of species
- Shift in ecological balance

Loss of Beneficial Uses

- Reduction in desirable fish species
- Shellfish contamination
- Contamination of drinking water sources
- Contamination of swimming beaches
- Loss of recreation and aesthetic value of state waters

In summary, the Part II B ***water quality*** technical criteria establish a baseline load of total phosphorus that can be allowed to leave a site through stormwater runoff. The goal of the criteria is to protect waterways from the adverse effects of increased pollutants.

The goal of the Part II B ***water quantity*** criteria is to assure that runoff from a developed site does not impact downstream properties or natural resources by restricting the peak flow and managing the volume. It also seeks to ensure that increased runoff does not exceed the capacity of a receiving stream channel in order to protect against channel erosion and flooding, or requires improvements where erosion and/or flooding have already occurred.

The Part II B criteria can be accomplished by reducing the volume of stormwater runoff that leaves a site through the use of Environmental Site Design principles, maintaining natural landcover conditions and installing DEQ approved BMPs rather than just conventional stormwater facilities for water quantity compliance.

As an inspector, you play a critical role in ensuring the approved plans, that are designed to meet the water quality and quantity criteria, are properly implemented during construction. Your role after construction continues to remain important. If proper maintenance of BMPs is not occurring, then they will not achieve the required water quality and/or quantity requirements.